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Hitachi, Ltd.  
Tokyo, Japan
- [32] Priorities

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July 12, 1968, Japan, 61788
- [33]
- [31]
- [54] GAS BLAST CIRCUIT BREAKER WITH PUFFER  
PISTON HAVING AN ELECTRODYNAMIC ASSIST  
IN THE FORM OF AXIALLY OVERLAPPING  
COILS

11 Claims, 6 Drawing Figs.
- [52] U.S. Cl.

200/148 A,  
335/149, 335/299  
H01h 33/91
- [51] Int. Cl.

200/148 A;  
335/147, 148, 149, 299, 255; 336/222, 224, 225,  
223
- [50] Field of Search
- [56] References Cited

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| Primary Examiner—Robert K. Schaefer       |        |                        |              |
| Assistant Examiner—Robert A. Vanderhye    |        |                        |              |
| Attorney—Craig, Antonelli, Stewart & Hill |        |                        |              |

**ABSTRACT:** A circuit breaker having an electromagnetic actuator which comprises at least one primary coil connectable to the circuit during breaking operation, a short circuit coil associated with said primary coil, means for movably supporting one of said primary coil and said short circuit coil, and compressing means for an arc-extinguishing gas mechanically connected with the movable one of said primary coil and said short circuit coil, said primary coil and/or said short circuit coil having a large axial length such that the electromagnetic repulsive force acting therebetween has a flat characteristic, the movable one of said primary coil and said short circuit coil being brought into overlapped relation with the other in a part of the moving stroke thereof.

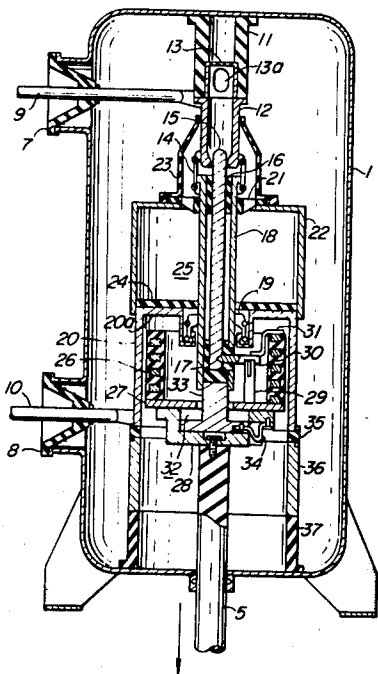


FIG. 1

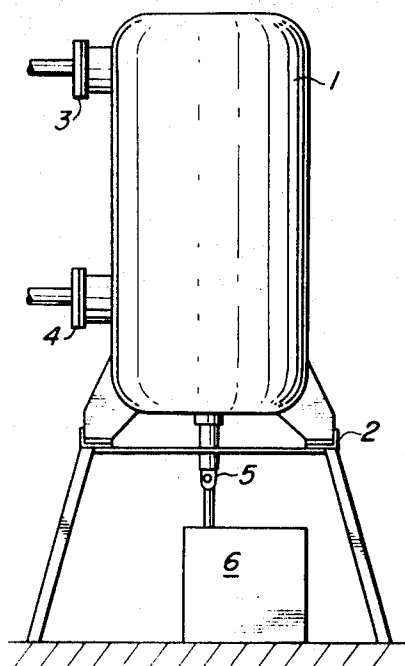
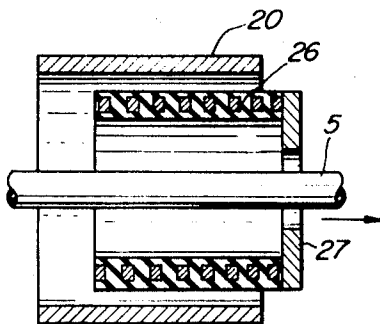


FIG. 3



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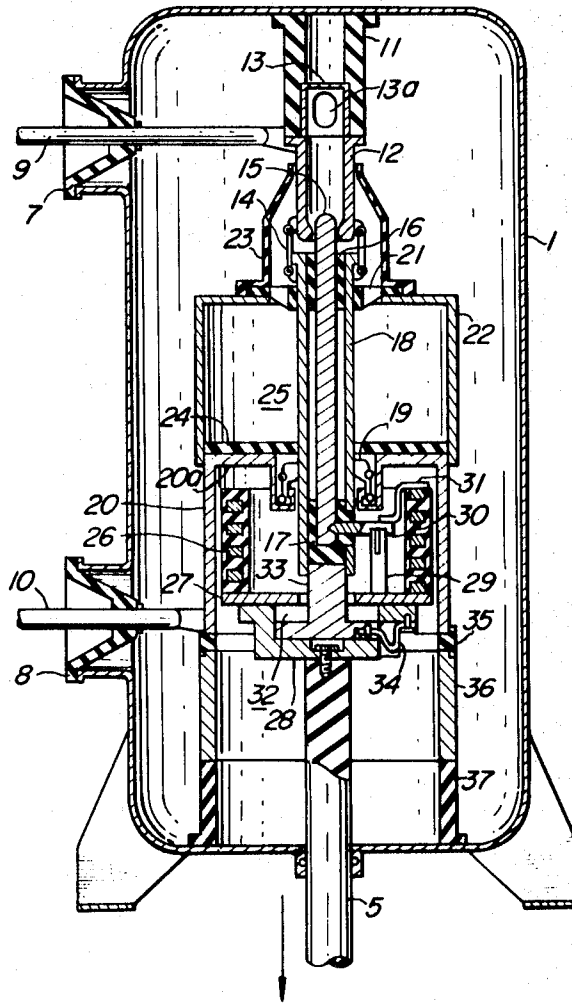
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FIG. 2



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FIG. 4

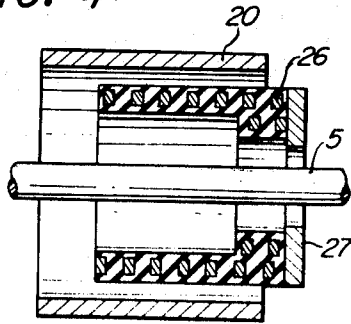


FIG. 5

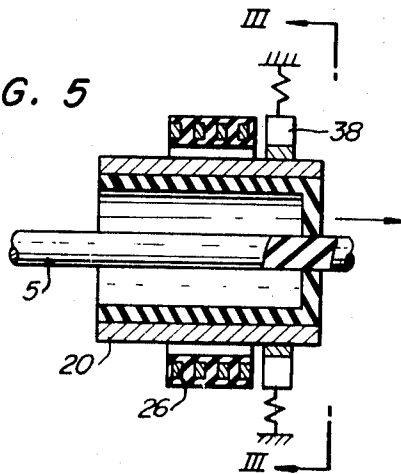
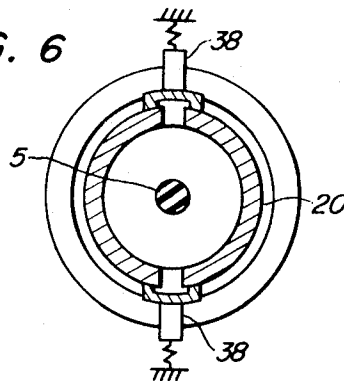


FIG. 6



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# **GAS BLAST CIRCUIT BREAKER WITH PUFFER PISTON HAVING AN ELECTRODYNAMIC ASSIST IN THE FORM OF AXIALLY OVERLAPPING COILS**

This invention relates to circuit breakers and more particularly to an actuating device for a circuit breaker of the so-called electromagnetic puffer type in which electromagnetic force produced by a current to be cut off is utilized to compress an arc-extinguishing gas which is directed to extinguish the arc generated as a result of the separation of contactors within a closed vessel containing therein the said gas.

In a circuit breaker wherein an arc-extinguishing gas is compressed prior to cutoff of current, the time required for effecting the desired degree of compression is extremely limited since compressing operation is started after the breaking instruction is given. A quite large actuating force is required in order to compress the arc-extinguishing gas up to a predetermined pressure within a limited period of time. A method which utilizes the electromagnetic force of a large current to cut off such as a short circuit current is disclosed, for example, in U.S. Pat. application Ser. No. 582,925 (Japanese Pat. Publication No. 8052/1967).

Electromagnetic force includes repulsive force and attractive force. In the case of actuating force for a circuit breaker of the puffer type, the electromagnetic repulsive force is more effective than the electromagnetic attractive force in view of the fact that the large force developed in the early stage of repulsion acts as a force of inertia later.

However, the electromagnetic repulsive force decreases abruptly with an increase in the distance between a primary coil and a short circuit coil. In a device of this kind, current is diverted to the primary coil after one of the primary coil and the short circuit coil is moved to a certain extent by an external actuator. Therefore, the maximum repulsive force cannot be utilized and the pressure of the arc-extinguishing gas increases gradually with the movement of compressing means such as a puffer cylinder and becomes maximum at a position corresponding approximately to 80 percent of the total distance of the movement. Thus, the operable range of the electromagnetic repulsive force is quite narrow and the electromagnetic repulsive force is weakened already when a sufficient actuating force is required. In view of the above fact, reliable operation cannot be expected.

Further, in the actuating device utilizing an electromagnetic repulsive force, initial surge occurring between the contactors during throw-in operation causes a current to flow through the primary coil. In the circuit breaker of this kind adapted especially for use in a high-voltage circuit, a large current flows through the primary coil to produce electromagnetic repulsive force between the primary coil and the short circuit coil. The electromagnetic repulsive force generated during the throw-in operation opposes the throwing force and may sometimes obstruct the throw-in operation.

It is an object of the present invention to provide a circuit breaker in which a primary coil and a short circuit coil constituting electromagnetic actuator means have a large axial length and are arranged to overlap each other in a part of the moving stroke so that a constant actuating force can be obtained even if current is diverted to the primary coil at whatever position of the primary coil and short circuit coil.

Another object of the present invention is to provide a circuit breaker in which an external actuator for effecting the breaking operation in the early stage of breaking and the throw-in operation is combined with the electromagnetic actuator means so as to direct a gas in an amount which is dependent on the value of current to be cut off.

A further object of the present invention is to provide a circuit breaker of compact and simple structure in which a puffer piston is fixed to the short circuit coil and a puffer cylinder is movable relative to the puffer piston.

Another object of the present invention is to provide a circuit breaker in which short circuiting means adapted for interlocked operation with a movable contactor connects the primary coil to the circuit during breaking operation and short

circuits the primary coil during throw-in operation so as to prevent flow of current through the primary coil even with the appearance of initial discharge and to ensure smooth throw-in operation.

In accordance with the present invention, there is provided a circuit breaker of the kind in which an arc-extinguishing gas enclosed therein is compressed prior to separation of contactors and the compressed gas is directed to the arc occurring between the contactors to extinguish the same, said circuit breaker comprising electromagnetic actuator means having at least one primary coil connectable to the circuit during cutoff of current, a short circuit coil associated with said primary coil, means for movably supporting one of said primary coil and said short circuit coil, and compressing means for the arc-extinguishing gas mechanically connected with the movable one of said primary coil and said short circuit coil, said primary coil and/or said short circuit coil having a large axial length such that the electromagnetic repulsive force acting therebetween has a flat characteristic, the movable one of said primary coil and said short circuit coil being brought into overlapped relation with the other in a part of the moving stroke thereof.

Other objects, features and advantages of the present invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is an external view of the circuit breaker according to the present invention;

FIG. 2 is an enlarged vertical sectional view of the breaker section of the circuit breaker shown in FIG. 1;

FIGS. 3 and 4 are schematic sectional views showing modifications of the primary coil in FIG. 2;

FIG. 5 is a schematic sectional view showing a modification of the short circuit coil shown in FIG. 2; and

FIG. 6 is a transverse sectional view taken along the line VI—VI in FIG. 5.

Referring to FIG. 1, a grounded tank 1 containing the breaker section is fixedly mounted on a support frame structure 2 which is secured to the ground. The grounded tank 1 has a pair of external terminal portions 3 and 4 on the same side so that current flows into and out of the grounded tank 1 through the external terminal portions 3 and 4. An actuating rod 5 extends movably into the grounded tank 1 through the lower bottom portion of the latter and external actuator 6 is operatively connected with the actuating rod 5 for actuating the breaker section contained within the grounded tank 1. In the case of a three-phase circuit, three grounded tanks 1 may be fixedly mounted on a support frame structure 2 and simultaneously actuated by a common external actuator 6.

As shown in FIG. 2, conical insulators 7 and 8 are disposed in the external terminal portions 3 and 4 for electrically insulating conductors 9 and 10 from the grounded tank 1, respectively. An arc-extinguishing gas such as sulfur hexafluoride ( $\text{SF}_6$ ) is filled within the grounded tank 1. The external terminal portions 3 and 4 as well as the portion through which the actuating rod 5 penetrates the lower bottom of the grounded tank 1 is hermetically sealed against leakage of the arc-extinguishing gas.

The conductor 9 is connected to a hollow stationary contactor 12 which is fixed to an insulator 11 suspended from the top portion of the grounded tank 1. A gas discharge box 13 having a port 13a is mounted in the insulator 11 so that the arc-extinguishing gas blown into the hollow space of the stationary contactor 12 can be discharged into the internal space of the grounded tank in a manner which will be described later.

When the circuit breaker is thrown in, a movable main contactor 14 contacts the outer peripheral portion of the stationary contactor 12 to secure the state of main contact. A movable arcing contactor 15 extends slightly into the hollow space in the stationary contactor 12 so as to produce an arc between it and the stationary contactor 12 when the main contactor 14 moves away from the stationary contactor 12 for breaking operation as described later. The movable arcing contactor 15

is concentrically supported through insulators 16 and 17 within a tubular member 18 of conductive material to which the movable main contactor 14 is fixed. Thus, the movable main contactor 14 and the movable arcing contactor 15 make substantially the same operation.

A current collector 19 fixedly supported by a flange portion 20a of a short circuit coil 20 is disposed around an intermediate portion of the outer peripheral wall of the tubular member 18, and the conductor 10 is connected to the short circuit coil 20. In FIG. 2, the short circuit coil 20 is shown as a coil having only one turn or a short circuit ring. However, the short circuit coil 20 may have a plurality of turns of conductor of small sectional area. A spiderlike support member 21 of insulating material is provided on the tubular member 18 at a part adjacent to the movable main contactor 14 and supports thereon a movable puffer cylinder 22 and a nozzle 23 of insulating material. The arc-extinguishing gas is filled within a puffer chamber 25 defined by the cylinder 22 and a stationary puffer piston 24 fixed to the flange portion 20a of the short circuit coil 20. During breaking operation, the arc-extinguishing gas compressed in the puffer chamber 25 is directed to the arc between the contactors by being guided by the nozzle 23.

A primary coil 26 molded in a mass of resinous material such as epoxy resin is fixed to a support member 28 of conductive material which is secured to the actuating rod 5, through an annular support member 27 of conductive material in the space defined within the short circuit coil 20. A knife edge contactor 29 is provided on the support member 27. The knife edge contactor 29 is in contact with a conductor 30 which is connected electrically with the lower end portion of the arcing conductor 15 and penetrates the tubular member 18 in electrically insulated relation therefrom. A flexible conductor 31 connects the primary coil 26 with the conductor 30 so that the primary coil 26 is substantially short-circuited when the knife edge contactor 29 is in contact with the conductor 30.

In a space 32 defined between the support members 27 and 28 of conductive material, an auxiliary actuating member 33 of conductive material is slidably disposed which extends through the opening of the support member 27 to be mechanically and electrically connected with the tubular member 18. A flexible conductor 34 is connected between the support member 28 and the auxiliary actuating member 33 to ensure intimate electrical coupling therebetween. The short circuit coil 20 is fixed to a member 36 of magnetic material through a member 35 of insulating material and the magnetic member 36 is fixed to the grounded tank 1 through a member 37 of insulating material. The magnetic member 36 attracts the primary coil 26 during breaking operation so as to apply a satisfactory actuating force. In order that electromagnetic repulsive force developed between the primary coil 26 and the magnetic member 36 due to interlinkage of the magnetic member 36 with the magnetic flux generated by the primary coil 26 may not obstruct the desirable attraction, the magnetic member 36 may be axially split into a plurality of sections so that it may not have one complete turn.

When the actuating rod 5 is driven in a direction of the arrow by the external actuator 6 in response to a breaking instruction, the auxiliary actuating member 33 makes a sliding movement in the space 32 and then engages the support member 27 so that the movable main contactor 14 and the movable arcing contactor 15 move together with the tubular member 18. Simultaneously, the knife edge contactor 29 moves away from the conductor 30 to release the short circuit of the short circuit coil 26. Further, the movement of the actuating rod 5 releases the state of main contact between the stationary contactor 12 and the movable main contactor 14 and an arc is generated therebetween.

In the meantime, the arc-extinguishing gas in the puffer chamber 25 is compressed to a certain extent and has now a certain pressure. The arc-extinguishing gas at pressure flows into the hollow space in the stationary contactor 12 by being guided by the nozzle 23 and the arc shifts from the movable main contactor 14 to the movable arcing contactor 15. Due to

the shift of the arc, current flows through the primary coil 26 to produce electromagnetic repulsive force between the primary coil 26 and the short circuit coil 20.

The timing of separation of the knife edge contactor 29 from the conductor 30 has not an appreciably important relationship with the timing of separation of the movable main contactor 14 from the stationary contactor 12, because an arc may also be produced between the knife edge contactor 29 and the conductor 30 when the separation of the knife edge contactor 29 from the conductor 30 takes place in simultaneous relation with the separation of the movable main contactor 14 from the stationary contactor 12. However, the arc voltage is equal to the voltage drop across the primary coil 26 and it is technically possible to suppress the voltage drop at a very small value. Further, the arc will immediately be extinguished by the insulating nature of the arc-extinguishing gas.

In cutting off a small current such as a rated current, the electromagnetic repulsive force generated between the primary coil 26 and the short circuit coil 20 does not have an appreciably large value and does not sufficiently contribute to the compression of the arc-extinguishing gas. This is very effective for cutting off such a small current. That is, when the arc-extinguishing gas is compressed to a high gas pressure during cutoff of small current, the gas at high pressure will be strongly directed to the arc to give rise to a current-chopping phenomenon which brings forth a disturbance in the circuit.

In cutting off a large current such as a short circuit current, a very large electromagnetic repulsive force is generated and transmitted to the auxiliary actuating member 33 through the support member 27 so that the arc-extinguishing gas is strongly compressed to be directed to the arc. In this case, the electromagnetic repulsive force imparts a strong actuating force for a long period of time due to the fact that the primary coil 26 and the short circuit coil 20 overlap each other over a substantial period of time and the primary coil 26 is attracted towards the magnetic member 36. Thus, a strong actuating force can always be obtained and a stable gas blow is directed to the arc even if current is diverted to the primary coil 26 at any time.

When the center of the primary coil 26 registers with the center of the short circuit coil 20, the electromagnetic repulsive force acts to compress the primary coil 26 in its radial direction and acts to expand the short circuit coil 20 in its radial direction, resulting in the absence of any effective actuating force in such a position. Thus, in a modification shown in FIG. 3, the primary coil 26 is asymmetrically wound in its axial direction, that is, the primary coil 26 is closely wound on the side connected with the annular support member 27 and is less closely wound on the side connected with the flexible conductor 31 so that the electromagnetic repulsive force can continuously effectively act from the beginning of actuation. Further, as shown in FIG. 4, the primary coil 26 may have a double wound portion on the side adjacent to the annular support member 27 so as to produce an asymmetrical magnetic field.

A peak appears more or less in the characteristic of the electromagnetic repulsive force as the primary coil 26 moves. Thus, as shown in FIGS. 5 and 6, the short circuit coil 20 may be axially split into two sections and short circuit bars 38 may be used to shift the short-circuiting position with respect to the short circuit coil 20 thereby to produce a stable electromagnetic repulsive force therebetween.

When the actuating rod 5 is urged in a direction opposite to the arrow in response to a throw-in instruction, the auxiliary actuating member 33 makes a sliding movement in the space 32 until finally it abuts the support member 28 thereby to start substantial actuation of the members including the movable main contactor 14. While the auxiliary actuating member 33 makes its sliding movement, the conductor 30 is contacted by the knife edge contactor 29 to short circuit the primary coil 26. Even when initial surge discharge takes place between the stationary contactor 12 and the movable arcing contactor 15 during the throw-in operation, current does not flow to the

primary coil 26 and flows from the knife edge contactor 29 to the short circuit coil 20 through the auxiliary member 33, the flexible conductor 34 and the support member 28. Therefore, no electromagnetic repulsive force is generated and the throw-in operation can smoothly be effected with a very small actuating force.

In the embodiment described above, the movable arcing contactor 15 is not in contact with the stationary contactor 12 in the thrown state of the circuit breaker. However, the movable arcing contactor 15 may be made slidable so that it contacts the stationary contactor 12. In this case also current does not flow to the primary coil 26 through part of the current flows through the movable arcing contactor 15, since the primary coil 26 is short-circuited. Thus, there is utterly no possibility that breaking operation takes place in the absence of a breaking instruction and the circuit breaker can satisfactorily be kept at its thrown state.

In the embodiment described above, the movable main contactor 14 is slidably connected with the actuating rod 5 through the auxiliary actuating member 33. However, the movable main contactor 14 may directly be connected with the actuating rod 5 without the use of the auxiliary actuating member 33. In such a case, the knife edge contactor 29 may be fixed to the flange portion 20a of the short circuit coil 20 so that it contacts the conductor 30 at a position prior to occurrence of initial discharge during the throw-in operation, that is, at a position at which no initial discharge does not occur. This arrangement exhibits the effect same as that exhibited by the embodiment described above. In the case of an arrangement as disclosed in U.S. Pat. application Ser. No. 582,925 cited previously in which electromagnetic drive is effected by a combination of a plurality of attraction coils and repulsion coils, all the coils may be individually or wholly short-circuited to prevent failure to throw in due to the initial discharge according to the present invention.

What is claimed is:

1. A circuit breaker for cutting off a load current to be carried through a contact between a stationary and movable main contactors, both contactors being opposite to each other, in which said current is diverted to an electromagnetic actuator means in an operation to separate said movable contactor from said stationary contactor by an external actuator and an electromagnetic force developed by said current is applied together with a driving force of said external actuator to compress an arc-extinguishing gas which is directed to the arc to extinguish the same, said electromagnetic actuator means comprising at least one primary coil to be diverted with said load current, a short circuit coil associated with said primary coil, such that a current is induced to said short circuit coil by said current diverted to said primary coil to thereby produce the electromagnetic force between both said coils, means for movably supporting one of said primary coil, and said short circuit coil, and compressing means for the arc-extinguishing gas mechanically connected with the movable one of said primary coil and said short circuit coil, said primary coil and/or said short circuit coil having a large axial length such that the electromagnetic force acting therebetween has a flat characteristic, the movable one of said primary coil and said short circuit coil being brought into overlapped relation with the other in a part of the moving stroke thereof.

2. A circuit breaker as claimed in claim 1, in which said primary coil in said electromagnetic actuator means is asymmetrically wound so as to produce a magnetic field which is asymmetrical in the axial direction of said primary coil.

3. A circuit breaker as claimed in claim 1, in which said electromagnetic actuator means comprises short circuiting means for short circuiting said primary coil during or prior to throw-in operation and releasing said primary coil during or prior to breaking operation.

4. A circuit breaker as claimed in claim 1, in which said short circuit coil in said electromagnetic actuator means is axially split in at least one portion thereof and the split portion is short-circuited with the movement of said primary coil or said short circuit coil.

5. A circuit breaker for cutting off a load current to be carried through a contact between a stationary and movable main contactors, both contactors being opposite to each other, in which said current is diverted to an electromagnetic actuator means in an operation to separate said movable contactor from said stationary contactor by an external actuator and an electromagnetic force developed by said current is applied together with a driving force of said external actuator to compress an arc-extinguishing gas which is directed to the arc to extinguish the same, said electromagnetic actuator means comprising at least one primary coil to be diverted with said load current, a short circuit coil associated with said primary coil such that a current is induced to said short circuit coil by said current diverted to said primary coil thereby to produce the electromagnetic force between both said coils, a member of magnetic material for attracting said primary coil toward it, means for movably supporting one of said primary coil or said short circuit coil and said member of magnetic material, and compressing means for the arc-extinguishing gas mechanically connected with said movable one of said primary coil or said short circuit coil and said member of magnetic material, said primary coil and/or said short circuit coil having a large axial length such that the electromagnetic repulsive force acting therebetween has a flat characteristic, one of said primary coil and said short circuit coil being brought into overlapped relation with the other in a part of the moving stroke thereof.

6. A circuit breaker according to claim 5, wherein said means for movably supporting primary coil includes an actuating rod fixedly attached to a first support member upon which an annular support member rests, said primary coil being disposed on said annular support member, and wherein said compressing means includes a puffer chamber fixedly mounted in a first cylinder, which in turn, is affixed to said short circuit coil at a flanged portion thereof, whereby during breaking operation, said arc-extinguishing gas is compressed in a puffer chamber formed by said cylinder and the flange portion of said short circuit coil.

7. A circuit breaker according to claim 6, wherein said movable contactors are formed by a pair of concentrically disposed conductors centrally arranged within said chamber, a center one of which has a conductor contact at the end thereof adjacent said primary coil while the outer one of said concentrically disposed conductors has formed thereon said movable main contactor and wherein a shorting switch is located within said primary coil and has one of its contacts affixed to said annular support member and the other of its contacts fixably attached to the winding of said primary coil, whereby, upon movement of said actuating rod, said switch will open or close dependent upon the direction of movement of said rod and said primary coil will be short or open circuited in response thereto.

8. A circuit breaker comprising:

a pair of terminals through which current normally flows during the closed condition of said breaker;

a stationary contactor electrically connected with one of said terminals;

a movable contactor disengagably slidable with respect to said stationary contactor, whereby current flows directly between said contactors during normally closed operation of said breaker and an arc forms between said contactors upon disengagement thereof during breaking;

means, coupled to said contactors, for supplying an arc-extinguishing gas upon disengagement of said contactors;

means for separating said contactors from each other, so as to interrupt the current normally flowing between said terminals, comprising an electromagnetic actuator arrangement including:

means for electromagnetically separating said contactors comprising:

a primary coil, normally short circuited during the flow of current between said terminals, and

a short circuit coil electrically connected to said movable contactors, one of said primary and secondary coils having a large axial length such that the elec-

tromagnetic force acting therebetween has a flat characteristic; and means for inducing an electromagnetic displacing force between said primary coil and said short circuit coil including:

means for simultaneously mechanically means for simultaneously mechanically displacing said contactors with respect to each other and for displacing said primary coil relative to said short circuit coil and for initiating current flow therebetween, said simultaneous displacing means including means for terminating the normally short-circuited condition of said primary coil and providing a current path therethrough, whereby an electromagnetic field between said primary and said short circuit coil will be generated to assist the separation of said contactors by said displacing means.

9. A circuit breaker according to claim 8, wherein said means for supplying an arc-extinguishing gas comprises a movable puffer cylinder mechanically coupled to said movable contactor and a stationary puffer piston affixed to said

short circuit coil.

10. A circuit breaker according to claim 8, wherein said movable contactor comprises a central contactor element and a tubular member, said tubular member being electrically connected directly to said short circuit coil and further including means, connected to said central contactor elements, for normally directing said central contactor through said short circuit coil to one of said terminals and for connecting said central contactor element through said primary coil and said short circuit coil to said one of said terminals during the breaking operation of said breaker.

11. A circuit breaker according to claim 10, wherein said normally directly connecting means comprises a knife edge contactor electrically connected to one end of said primary coil and a conductor connected directly to said central contactor element and the other end of said primary coil, said knife edge contactor and said contactor being displaced with respect to each other.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,621,171 Dated November 16, 1971

Inventor(s) Yoshio YOSHIOKA

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Page 1, column 1, line 10,

"29868" should read --61788/68--

line 11,

"48490" should read --29868/68--

line 12,

"61788" should read --48490/68--

Signed and sealed this 23rd day of May 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.  
Attesting Officer

ROBERT GOTTSCHALK  
Commissioner of Patents